Description

OPTIMIZED APERTURE SHAPE FOR OPTICAL CD/PROFILE METROLOGY

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from U.S. provisional application no. 60/227,739, filed August 24, 2000.

TECHNICAL FIELD

The invention relates to optical measuring instruments for samples containing grating-like features, and in particular for determining critical dimensions (line width, etc.), profile or shape, and similar parameters of interest of the grating-like features. The invention relates especially to elements of such instruments for providing a specified illumination of the sample features.

BACKGROUND ART

Optical scatterometry, reflectometry, or ellipsometry methods can be used to measure grating profile shapes and critical dimensions that are significantly smaller than the measurement instrument's optical wavelength(s) and imaging resolution. With this technique, a grating sample's reflectivity in one or more diffracted orders (typically the zero order) is measured at multiple wavelengths, incidence angles, and/or polarization states, and a theoretical electromagnetic scattering model is fit to the measured data to determine grating parameters such as profile shape and line width. For example, Fig. 1 schematically illustrates reflectometer-type measurement instrument that can be used for grating measurement. Illumination from a source 101 transmits through a beam splitter 102, and is focused by an objective lens 103 onto a small focus spot 104 on a grating sample 105. Reflected radiation is diverted by

beam splitter 102 toward a radiation-sensing detector 106. Reflectivity data is acquired over a range of wavelengths and is computationally processed to determine grating parameters such as line width, thickness, etc. The illumination system in Fig. 1 has a limiting aperture 107 whose size and shape determines the size and shape of the diffraction-limited focus spot 104 on grating 105. Typically, the focus spot must be large enough to cover multiple grating lines to achieve good measurement sensitivity. But if the grating is close to adjoining structures a large spot size may result in degraded measurement performance due to proximity effects. This tradeoff is illustrated in Fig.'s 2A and 2B. These figures show a plan view of grating 105 comprising grating lines 201a, 201b, etc. of limited length. (The grating lines may actually be much longer, but the useful area for measurement may be limited due to other structures overlying or underlying the grating.) The limiting aperture, illustrated as circle 107, controls the size and shape of the focus spot 104. A large aperture results in a small focus spot which does not cover sufficiently many grating lines to achieve good measurement sensitivity (Fig. 2A). A small aperture results in a large focus spot covering many grating lines (Fig. 2B), but in this case the focus spot extends outside of the measurable grating region 105, resulting in degraded measurement performance.

DISCLOSURE OF THE INVENTION

The invention alters the prior optical metrology instrument to eliminate the undesirable tradeoff by providing the instrument with an elongate limiting aperture. An illumination source directs light along an illumination path. An elongated pupil aperture is located in that illumination path. An objective lens focuses the light received from the aperture to the sample. The elongated pupil aperture and the objective lens together define an elongated illumination spot on

the sample, wherein the aperture and illumination spot have respective long directions that are perpendicular to each other. When measuring grating-like microstructures on a sample, the sample is supported in a measurement relation to the instrument such that the illumination spot is oriented generally transverse to the linear elements of those microstructures.

The objective is preferably characterized by a low numerical aperture so as to produce focused illumination that has only a narrow range of incidence angles in the direction that is generally transverse to the linear elements of the microstructure.

The illuminated sample produces a characteristic optical signature, such as a reflected intensity spectrum, that is indicative of parameters of interest of the microstructure. The instrument has collection and detection optics to measure the optical signature for subsequent processing. For example, the processor may determine a best fit of the detected signature to a theoretical signature corresponding to a specific set of values for the parameters of interest.

The grating-like structure can also be a two-dimensional bigrating, in which case the illuminated spot may correspond to a row or column of the bigrating.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side schematic view of an optical metrology instrument showing those elements that are common to both the prior art and the present invention.

Figs. 2a and 2b are top schematic views of a circular illumination spot produced over a diffractive feature of a sample by instruments like that in Fig. 1 with circular limiting apertures according to the prior art.

Figs. 3 and 4 are top schematic views of elongated illumination spots produced over grating and

bigrating structures on a sample by instruments like that in Fig. 1 with elongated limiting apertures according to the present invention.

BEST MODE OF CARRYING OUT THE INVENTION

Fig. 3 illustrates the method of the present invention which circumvents the spot size tradeoff. Again, Fig. 3 shows a plan view of the grating 105, limiting aperture 107, and focus spot 104. The aperture has an asymmetric, elongated shape (elliptical in this example, although it could alternative be rectangular or could have some other optimal shape). The spot size is consequently elongated along the transverse direction so that it extends over many grating lines, but stays confined within the grating region 105. The aperture size and shape could be variable so that it can be independently optimized for different grating geometries. This method would be useful for applications where the usable measurement area is limited either by the grating size or by other structures deposited above or below the grating. One potential application would be measuring two-dimensionally periodic structures ("bigratings"). For example, Fig. 4 illustrates a bigrating 401 comprising rectangular grating cells (e.g. cells 402a, 402b, etc.) in a rectangular array. The focus spot 104 is confined to a single row of the array so that the grating pattern can be modeled as a simple one-dimensionally periodic structure within the illumination area.